astray as the English have been. We shall, moreover, be free from the pressure of a royal court which dislikes biological science, and from the influence of the personal prejudices of the sovereign, still powerful enough in England to have much weight in legislation on questions outside of Whig and Tory politics. Still, American physiology is by no means secure, unless its leaders take warning by the English disaster. They have, in consequence of British legislation, an opportunity to make the United States the chief seat of physiological research among the English-speaking peoples; and it will be a lasting disgrace to them if they let it slip. If, while freely admitting that they believe it their duty to experiment on living animals, they will be on the alert to correct at once the falsehoods and exaggerations of the fanatics; to take pains to teach the public how much the scientific treatment of disease depends on physiological, therapeutical, and pathological research; and to make it widely known how very small a percentage of vivisections involve more pain than that felt by a man on receiving a hypodermic of morphia, — then there is little doubt they will be allowed to carry on without hindrance their beneficent work. The only danger lies in the ignorance of the great majority of ordinarily well-informed people regarding such subjects. Secrecy, not publicity, is what American physiology has to fear.

A HEARING OF BIRDS' EARS.[1] — II.

Let us next confine attention to the ossicles of the ear. Those familiar with these little bones, only as they occur in man or any other mammal, need to be cautioned that their anatomical arrangement, and to a great extent their physiological characters, are very different in birds and other reptile-like vertebrates. Presuming, of course, upon the reader's thorough knowlege of the human case, we will demonstrate these bones in their proper relations and offices in birds, as elements of the lower jaw and hyoid bones (mandibular and hyoidean arches).

The malleus is the proximal element of the meckelian cartilage (figs. 1, 2, *mk*), a gristly rod about which the lower jaw-bone is developed in membrane. Becoming segmented off from the rest of the meckelian rod, it is in mammals withdrawn into the tympanic cavity, disconnected from the jaw-bone, and connected with the incus, its *processus gracilis* lying in the glaserian fissure. The jaw-bone then articulates directly with the glenoid cavity of the squamosal, forming the temporo-maxillary articulation. In any bird the malleus remains outside the ear, and acquires comparatively enormous dimensions, with the peculiar shape shown in fig. 1, *q* (see also fig. 2, *q*). This

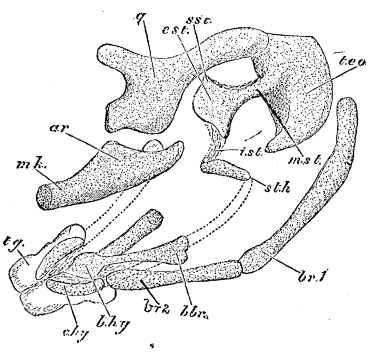

Fig. 2. — The post-oral arches of the house-martin, at middle of period of incubation, lateral view, × 20 diameters. *Mk*, stump of meckelian or mandibular rod, its articular part, *ar*, already shapen; *q*, quadrate bone, or suspensorium of lower jaw, with a free anterior orbital process and long posterior otic process articulating with the ear-capsule, of which *teo*, tympanic wing of occipital, is a part; *mst*, *est*, *sst*, *ist*, *sth*, parts of the suspensorium of the third post-oral arch, not completed to *chy*; *mst*, medio-stapedial, to come away from *teo*, bringing a piece with it, the true stapes, or *columella auris*, the oval base of the stapes fitting into the future *fenestra ovalis*, or oval window, looking into the cochlea, or inner ear; *sst*, supra-stapedial; *est*, extra-stapedial; *ist*, infra-stapedial, which will unite with *sth*, the stylo-hyal; *chy* and *bhy*, cerato-hyal and basi-hyal, distal parts of the same arch; *bbr*, *br*1, *br*2, basi-branchial, epi-branchial, and cerato-branchial pieces of the third arch, composing the rest of the hyoid bone. (After Parker.)

quadrate bone, as it is called in birds, looks something like an anvil, and has often been mistaken for the incus: on the other hand, from its function in supporting the *membrana tympani* in part, it has been malidentified with the tympanic bone (external auditory process). It is very freely articulated at both ends, rocking back and forth with the movements of the jaws. It normally has articulation with five separate bones: 1. By its lower end, which is bitubercular, with the articular piece of the mandible (lower jaw), forming the true temporo-maxillary articulation; 2. By the outer extremity of its lower end with the quadrato-jugal bone (fig. 1, *qj*), which is the posterior element of the zygomatic arch, continued forward by the jugal or malar bone (fig. 1, *j*) to the superior maxillary (fig. 1, *mx*); 3. By the inner extremity of its lower end with the ptery-

[1] Continued from No. 34.

goid bone (fig. 1, *pg*), and so with the palate-bone (fig. 1, *pa*) and superior maxillary (*mx*), 4, 5. The head of the bone normally articulates both with the squamosal (fig. 1, *sq*) and with the pro-otic (fig. 4, *po*, here seen inside the cranial cavity). A long spur of the quadrate, its orbital process, projects freely into the orbital cavity, as shown in fig. 1, where the still cartilaginous tip of the orbital process reaches to the round white hole marked 2 (*optic foramen*). Now, the osseous articulations and muscular tractions are such, that, when the mouth is opened, the malleus rocks forward upon its squamosa-petrosal articulation (4, 5, of above enumeration), and pushes upon the zygomatic and pterygo-palatal bars, causing the upper mandible to rise as the lower jaw is depressed; the upper jaw hinging upon elasticity of, or a joint at, the bones of the forehead. Thus the malleus-quadrate is here seen in its proper relation to the jaw-parts as nothing at all of an *ossiculum auditus*, except in so far as it hinges upon parts of the temporal bone, and helps to support the ear-drum. It has no direct connection whatever with the rest of the ossicles.

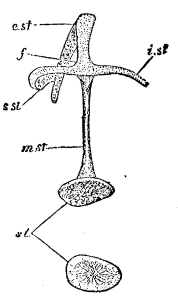

FIG. 3. — Mature stapes of fowl, about × 4. (After Parker.) *st*, its foot, fitting *fenestra ovalis; mst*, main shaft, or medio-stapedial element; *sst*, supra-stapedial; *est*, extra-stapedial; *ist*, infra-stapedial, its end representing a rudimentary stylohyal; *f*, a fenestra in the extra-stapedial. (See *st, in situ*, fig. 1, and its embryonic formation, fig. 2.)

It will be best to take the stapes next. Fig. 3 shows the mature stapes of the domestic fowl, enlarged about four times, and indicates its several elements which have received special names. It is practically the same bone so named in man, but includes incudial as well as some other elements. In form it is not at all stirrup-like, being trumpet-shaped, with a slender cylindrical shaft, expanded oval foot, and a crossbar and other pieces at the distal end. It is therefore oftener called the *columella auris*, or sounding-post of the ear. In skulls prepared with sufficient care, the stapes may be seen *in situ*, as in fig. 1, *st*, — an extremely delicate rod, stepped into the *fenestra ovalis* by its foot, the other end protruding into the tympanum, and bearing the additional hammer-like or claw-like elements. A stapes I have just picked out of an eagle's ear is a fourth of an inch long, with a stem as fine as a thread of sewing-silk, but a stout foot, and, at the tympanic extremity, a still finer hair-like process half as long as the main stem, from which it stands out at right angles; while there appears to have been another similar claw, which has broken off from such a cross-like object as *st* in fig. 1.

Embryological study is required to demonstrate the stapes as the proximal element of the hyoidean apparatus, quite as the malleus is of the mandibular arch. Reference to fig. 2 should make this clear. Here the malleus, *q*, extends from *teo*, the tympanic wing of the exoccipital, to *ar*, the articular element of *mk*, the meckelian rod whence *q* has been segmented off, leaving the 'temporo-maxillary articulation' between *q* and *ar*. This chain of bones, including others to be developed about and beyond the stump of *mk*, is the lower jaw, or mandibular arch. Now, quite a similar arrangement is shown in the chain of bones in the tongue or hyoidean arch. From *teo* stands off a rod of bone, *m st*, the medio-stapedial element, or main shaft of the stapes, to be segmented away from *teo*, the place of this segmentation to become the fenestra ovalis. The medio-stapedial rod expands at its end; the upper part of the expansion, never separating from the rest, is the supra-stapedial element = mammalian incus, *s st* in figs. 2, 3. An infra-stapedial element, just forming in fig. 2, *ist*, completed in fig. 3, *ist*, connects with the piece marked *st h* in fig. 2. This *st h* is the stylo-hyal = human 'styloid process of the temporal,' which connects in man by the 'stylo-hyoid ligament,' with the 'lesser cornu of the hyoid bone,' which is the cerato-hyal, *c hy*. In birds, the distal parts of the hyoid arch (composed of the numerous pieces lettered in fig. 2, but which need not longer detain us) become entirely separated from the proximal, the tongue-bones being quite otherwise affixed to the skull; while the proximal parts of the same arch are shut up in the tympanic cavity, where they extend from the *membrana tympani* to the *fenestra ovalis*, constitute all there is of *ossicula auditus*, and consist of the stapes itself (including the several elements specified).

So, therefore, avian malleus or quadrate-bone = human malleus as proximal element of mandibular arch, retaining articular connection with its own arch, but not acquiring character or connections of a human *ossiculum auditus*.

So, therefore, avian stapes or columella = human stapes + incus, as proximal elements of hyoidean arch, not retaining connection with its own arch, but acquiring characters and connections of *ossicula auditus*.

These are the reasons why a bird's lower jaw does not articulate directly with the squamosal,

why the hyoid bones do not articulate at all with the skull, why the malleus is outside the ear, and why there is apparently but one ossicle in the tympanum, of the particular shape shown in fig. 3.

(To be continued.)

THE PSYCHOLOGICAL MECHANISM OF DIRECTION.

Were it admissible that one person should add to the work of a living author, I might call this paper a supplement to Mr. Francis Galton's Human faculty. My object is to explain the subjective mechanism by which I preserve the consciousness of direction. How far others adopt the same mechanism, I am not fully aware, but am inclined to think that what is fundamentally the same system is employed by nearly every one; but I doubt whether the details are always the same, and the matter appears of sufficient interest to be discussed.

To be conscious which way he is going, one must keep in mind some system of directions. It is true, that, so far as finding one's way about in a place with which he is fully acquainted is concerned, no attention to direction is necessary. One knows that he must turn here to the right, and there to the left, and must follow certain familiar paths, all of which he can do without attending to direction. It is probable that most animals, and possible that some men, have no system except this. Regarding such a limitation as exceptional, we must suppose that in general, men, in going about, have constantly in mind an idea that they are going in a certain definable direction. A direction can, however, be defined only by reference to the direction of some line taken as a standard of reference; and it is this standard of reference, as I have always employed it, which I shall now describe.

I. I continually carry around with me a conception of four horizontal lines, which I shall call co-ordinates, going out in four cardinal directions. I shall call these directions east, west, north, and south; but it must be understood that they have no necessary relation to the actual points of the compass, being purely subjective. This system of co-ordinates is employed, I think, by most or all men.

II. These four cardinal directions are conceived of as *absolute* directions, and not as defined relatively to any particular line on the earth's surface. They have remained unchanged since the earliest memories of childhood. To be more explicit, the ideal or subjective west is the direction in which I was facing, when, as a child, my father explained to me which was the right hand, and which the left; the ideal north is the direction towards which my right side was then turned; the ideal south, that towards which the left side was turned; while east was behind my back.

I have always since imagined myself as conscious of these four absolute directions, and therefore at any moment can face as I imagine myself to have been facing on the occasion referred to. I do not know whether the co-ordinates have the same absolute character with other men, but think it highly probable that they do, since absolute directions must be more easily thought of than relative ones.

III. With some limitations, to be soon referred to, the system of directions is quite independent of the will. Once fixed in a place, a street, or a house, they are an inseparable component of the situation, and forever unalterable so long as the identity of the place is recognized. Once in a room of which I conceive a certain side to be the absolute west, by no act of the will, and by no consciousness that some other side is the west, can I change the subjective impression. Of course, however, one is liable on going into a strange place, or on walking about without sufficient attention, to be mistaken as to his direction; and thus I am subject to a kind of trouble or confusion which I never heard any one else describe, and which, therefore, I can hardly suppose to be universal. Some instances will illustrate the matter better than general statements.

I recently went to a hotel in Paris, where I had stopped eight years before. While driving into the court, and just as the carriage was stopping, my attention was momentarily occupied in speaking to one of the attendants. Getting out of the carriage, I remarked, as I supposed, that the offices of the hotel had all been moved from the north to the west side of the court. I may anticipate by saying that this was an illusion arising from the very minute circumstance that the carriage, during the moment that I was speaking to the attendant, had turned at a right angle from facing north to facing east; but being unconscious of this change, and not looking around the court, I supposed that the carriage was still directed towards the ideal north. I entered the elevator, was carried to an upper story, shown through several long passages, and into a room, preserving the changed system of co-ordinates of which I was entirely unconscious. Had it been my first visit to the hotel, no confusion would have resulted, since every thing